Interrelated Water Management Plan Program Funds Application

Deadline for Applications August 28, 2006

Project Sponsor(s): South Platte Natural Resources District and the North Platte Natural Resources District

Project Name: Remote sensing technology to produce consumptive water use maps for the NE Panhandle

Total Amount Funds Requested from the Interrelated Water Management Plan Program Fund (IWMPPF): $ 246,649.00

Years of funding requested (select one): ☐ 1 ☐ 2 ☑ 3

Amount Requested from the Fund Year 1: $ 91,700.00

Amount of Local Match Offered Year 1 (must equal at least 20% of funding requested from the IWMPPF): $ 22,926.00

Contact - Name: Rod Horn and Ron Cacek

Title: Managers, SPNRD & NPNRD

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Is this a continuation request for a project previously funded by the Commission? ☐ YES ☑ NO

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Project Overview: In **300 words or less** provide an overview of the project for which you seek funding. If you are asking the Natural Resources Commission to fund only a portion of the project, indicate the components for which you seek funding.

The goal of the project is to accurately quantify net consumptive water use (CWU) for different crops by processing LANDSAT images from 1997, 2002 and 2005. The initial CWU maps will be developed by the University of Idaho (UI) using the Mapping EvapoTranspiration with High Resolution and Internalized Calibration (METRIC) algorithms. The South Platte NRD, the North Platte NRD, UI and the University of Nebraska will work together to develop, test and demonstrate tools that will take these CWU maps and turn them into usable products for planning, managing and regulating groundwater resources. UI will provide training in applying the METRIC equations. The tools/products to be developed and demonstrated include: (1) Developing CWU maps for areas irrigated by groundwater sources and surface water. (2) Sampling of project area CWU data to develop locally calibrated Kc curves for specific crops [alfalfa, wheat, corn, dry beans and sugar beets]. (3) Producing maps of net differences in CWU from irrigated agriculture and CWU from rainfed (dryland) agriculture and; (4) Producing maps of net differences in CWU from irrigated agriculture and CWU from natural vegetation. The year 1997 represent the cutoff year for groundwater adjudication, 2002 was an exceptionally dry year, and 2005 was a normal to slightly above normal year after 3 years of some form of water restriction and conservation measures. The project will develop capability to interpret CWU maps for water balances and will develop crop curves for specific crops to delineate irrigated and non-irrigated acres for the reference years listed. The net water use during 1997, 2002, and 2005 will provide the NRDs with the information they need to conjunctively manage ground and surface water as mandated by Nebraska Law LB962. An NRCS Conservation Innovation Grant will be the main support for this project. DNR funds will allow additional resources to enhance the project.

On behalf of the sponsor(s) named above, I hereby certify that the information contained in this application, including all attachments, is true, accurate and complete.

Authorized Signature of Natural Resources District	Title	Date
Typed or Printed Name of Authorized Signatory	Typed or Printed Title	

PROJECT DESCRIPTION

In ten pages or less, provide a discussion of your project. Please include:

- **Introduction**
  Justification for why the project is needed.
  Identify any other activities ongoing or planned that relate to the project.

- **Project Objectives**
  Describe the specific objects of the project for which you are seeking grant funds.

- **Project Tasks**
  Identify what activities will be conducted by the project. For technical studies please provide sufficient information on the methods that will be used so that there can be an independent assessment of the ability of these methods to achieve the objectives of the study.

- **Project Timeline**
  For multiyear projects please list what activities are to be completed in each year for which Interrelated Water Management Plan Program Funds are requested.

- **Partnerships**
  Identify the roles and responsibilities of agencies and groups involved in the proposed project regardless of funding source.

- **Budget**
  Identify the cost of the entire project. Costs must be listed in the following tables. Please indicate the source of funds for the project and provide a detailed budget for each major task or work element for which requested grant funds or match funds will be allocated.

Remote sensing technology to produce consumptive water use maps for the Nebraska Panhandle

Introduction:

Recurrent droughts across the High Plains and Inter-Mountain West have magnified the problem of declining ground water resources. The High Plains Aquifer (HPA), often referred to as the Ogallala aquifer, underlies parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Nearly 30 percent of the ground water used for irrigation in the United States is extracted from the HPA (Weeks et al., 1988).

A significant proportion of the HPA is located within Nebraska. Ground water-levels began declining in some parts of Nebraska after extensive irrigation development began in the 1960's (Figure 1.). The passage of Nebraska LB 108 in 1996 recognized the relationship between ground and surface water and LB962 (2004) provided new regulatory measures to conjunctively manage ground water and surface water. This legislation will lead to changes in the way water resources are managed. In the North Platte River Basin, surface water deliveries have been reduced and Natural Resource Districts (NRDs) have adopted or are considering allocations for ground water pumping in some areas. The North Platte Natural Resources District (NPNRD) established a ground water management area and closed the Pumpkin Creek watershed to new well drilling in 2001 and currently allocates 14 acre-inches for irrigation. The South Platte NRD (SPNRD) established an integrated ground water management subarea and closed the Lodgepole Creek Valley Watershed to new large capacity well drilling in 2002.

Under current Nebraska law, surface water is regulated by the Nebraska Department of Natural Resources (DNR) and ground water is regulated by the 23 NRDs. According to DNR, water demands meet or exceed supply limits in many basins and they have designated these basins as fully appropriated or over-appropriated. Much of the Nebraska Panhandle is in the fully or over-appropriated areas. The key to the success of integrated management plans is to understand how groundwater and surface water supplies interact with actual **c**onsumptive **w**ater **u**se (CWU). The dilemma for management entities is how to maintain profitable agricultural operations that are dependent on irrigation water while protecting surface and ground water resources to comply with water compacts or basin-wide water management goals.

Actual CWU from irrigated agriculture is almost exclusively the principal consumer of irrigation in the High Plains. CWU demands by irrigated crops in the HPA generally exceed natural precipitation and require supplementation from ground and surface water. Understanding and quantifying actual CWU across NRD management areas is essential to manage water resources. However, considerable uncertainty exists regarding the spatial and temporal distribution and variability of CWU estimates. The variation comes from differences in weather, precipitation timing and quantity, soils, crops and cropping systems, irrigation methods, their management and efficiencies, and consumptive use of water by natural vegetation.

Remote sensing technology has been used in land use mapping, geology, mineral exploration, to locate river beds and lakes, and to assess water resources, coastal environments, and forestry and rangeland resources. Application of algorithms to compute CWU by assessing

the energy balance using Surface Energy Balance Algorithm for Land (SEBAL) (Bastiaanssen et al., 1998) and Mapping EvapoTranspiration with High Resolution and Internalized Calibration (METRIC) (Allen et al., 2005) is a prudent approach. Accurately quantifying CWU is necessary to provide prediction of the timing and the spatial extent of potential depletions or gains in both the short-term and in the long-term management of surface and ground water used for irrigated systems. This information is also required to support hydrologic modeling such as the Cooperative Hydrology Study (COHYST) model which is used extensively in Nebraska.

METRIC has been recognized as a valuable tool for water resources management by the Idaho Department of Water Resources (IDWR). IDWR and UI, in partnership, have routinely applied monthly and seasonal ET maps created by METRIC to: 1) set water budgets for hydrologic modeling, 2) monitor compliance with water rights, 3) support water resources systems planning, 4) estimate aquifer depletion, 5) support ground-water model calibration and operation, 6) estimate water use by irrigated agriculture, 7) estimate historical water use for water rights buyouts, 8) develop populations of K_c curves and establish mean curves for south-central Idaho, and 9) evaluate relative performance of irrigation canal companies by comparing ET with diversions.

Other applications of METRIC include (a) the Imperial Irrigation District of southern California where ET maps were used to document water consumption and salinity impacts and to support environmental monitoring and (b) the Middle Rio Grande basin of New Mexico to provide the Department of Justice with maps of net water consumption for use in water rights litigation, and to support Bureau of Reclamation efforts to improve and automate their AWARDS/ET-Toolbox software. The references are given:

1. Bastiaanssen, W.G.M., M. Menenti, R.A. Feddes, and A.A.M. Holtslag. 1998. A remote sensing surface energy balance algorithm for land (SEBAL). 1. Formulation. Journal of Hydrology. 212-213:198-212.
2. Tasumi, M., R. G. Allen, R. Trezza, J. L. Wright. 2005a. Satellite-based energy balance to assess within-population variance of crop coefficient curves, *J. Irrig. and Drain. Engrg*, ASCE 131(1):94-109.
3. Tasumi, M., R. Trezza , R.G. Allen and J. L. Wright. 2005b. Operational aspects of satellite-based energy balance models for irrigated crops in the semi-arid U.S. *J. Irrigation and Drainage Systems.* 19:355-376.
4. Allen, R.G., M. Tasumi, and R. Trezza. 2005c. Benefits from Tying Satellite-based Energy Balance to Ground-Based Reference Evapotranspiration. International Conference on Earth Observation for vegetation monitoring and water management. Naples, Italy, 10-11 Nov. 2005
5. Weeks, J.B., Gutentag, E.D., Heimes, F.J., and Luckey, R.R., 1988, Summary of the High Plains regional aquifer-system analysis in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Professional Paper 1400-A, 30 p.

Project Objectives:

The overall goal of this project is to develop remote sensing image acquisition and computing expertise using the METRIC procedure to produce area-specific CWU maps that can

be used to characterize and describe the dynamics of CWU. The specific objectives are to develop, test and demonstrate the tools that will take these CWU maps and turn them into immediately usable products for planning, managing and regulating groundwater resources. The tools and products that will be developed and demonstrated include: (1) Developing CWU maps for areas irrigated by groundwater sources and by surface water supplies. This will help develop water balances for these areas for assessing recharge. (2) Sampling of CWU data across the project area and develop locally calibrated Kc curves for specific crops [alfalfa, spring wheat, corn, and sugar beets]. This information is critical in setting irrigation scheduling, and in ground-water modeling work. (3) Produce maps of net differences in CWU from irrigated agriculture and CWU from rainfed (dryland) agriculture and; (4) Produce maps of net differences in CWU from irrigated agriculture and CWU from natural vegetation. The CWU maps will be used to estimate net water use during the 1997, 2002 and 2005 growing seasons.

Project Tasks:

Calibration and application of METRIC is technologically demanding and requires experience and expertise and understanding of physical processes and subtle, inner workings of the energy balance equations. Funds will be used to subcontract with the University of Idaho who will provide training in applying the METRIC equations, as it is critical to understand the process including assumptions, and to make consistent and dependable decisions. The training is essential to identify when the underlying assumptions must be changed to fit a particular condition so that these can be communicated to local managers as well as to the METRIC appliers. The training is also important so local NRDs have a technician who is educated and trained in the overall process that they can depend on for feedback. By the end of the project period, the NRDs will be better prepared to develop independently the routine CWU products.

Nebraska has a well developed system of regional weather stations that provides real-time reference ET (ET_r) as part of the High Plains Regional Climate Center (HPRCC). The current procedure for estimating actual CWU includes the commonly used crop coefficient (K_c) times reference ET_r method, where a 'representative' K_c curve is applied that describes the CWU from a specific crop relative to the ET_r over specific periods of time. While HPCC data provides ETr estimates, we still do not have a practical way of applying it on a watershed scale across time to derive CWU estimates. METRIC has the ability to do large scale areas that encompass both spatial and temporal variability without time consuming and costly research.

The K_c - ET_r approach is a conservative method that has had wide application for more than 40 years. The procedure is fairly accurate with an error of approximately +/- 20% (Allen et al., 2005a). Errors can be biased high or biased low for a particular region due to specific crop characteristics and cultural behavior of the region. Biases in K_c also result from water shortage that may be undocumented or that was not reflected in the development of a specific K_c curve. With the varying water availability during the past 5 years, this is a major concern as not all crops were 'fully irrigated'.

Substantial uncertainty exists in the ability of single K_c data sets typically derived for specific crop varieties to accurately estimate CWU for the wide range of conditions in the Nebraska Panhandle area. Impacts by irrigated agriculture on water resources are essentially

caused by differences between CWU from irrigation and CWU from natural vegetation. These differences represent the net depletion to the ground-water source. Both of these CWU amounts are best determined by accurate satellite-based energy balance due to the potentially large spatial and temporal variations.

The project area consists of 9 watersheds within the boundaries of two Natural Resources Districts, the North Platte NRD, and the South Platte NRD (Figure 2). There are about 4,449 irrigation wells in the project area. Satellite imagery across path 33 and row 31 covers almost 80 percent of the project area (figure 3). There are 4 watersheds located within the boundaries of NPNRD. They are 10180012 (Horse), 10180009 (Middle North Platte-Scottsbluff), 10180013 (Pumpkin Creek), and 10180014 (Lower North Platte). Annual precipitation received in the area averages about 13.2 inches. Currently, there are approximately 3,025 registered irrigation wells in the NPNRD, including 427 wells in the Pumpkin Creek Management Sub-Area (Figure 4). There are 5 watersheds located within the boundaries of the SPNRD. They are 10190015 (Upper Lodgepole), 10190016 (Lower Lodgepole), 10190017 (Sidney Draw), and 10190018 (Lower South Platte). In 2006, the District completed certification of 133,457 total irrigated acres consisting of 1,312 registered irrigation wells.

Project Timeline:

LANDSAT images for 1997, 2002 and 2005 will be selected for this project. We will apply METRIC processing algorithms to LANDSAT 5/7 TM images collected over a growing season (April to October). The primary output products will be actual CWU, delivered as ArcInfo Grid raster data. Crop coefficient (K_c) raster data developed during the image processing will be included. All four raster coverages, can be resolved to one value for each pixel as ArcInfo Grids. Cloud-free images that have the most coverage during the growing season will be selected from the suite. A total of 8 to 12 image dates should be processed between April 15 and October 15. Following the processing of the LANDSAT images, CWU and K_C maps, by month, will be constructed by interpolating and integrating between images using ET_r. A crop classification will be made, including some amount of quality ground-truth data on crop type from the populations of K_C by crop. Crop coefficient curves for specific crops [alfalfa, wheat, bean, and sugar beet] will be developed after year 1.

Project Time Line

Activities	Year 1	Year 2	Year 3
Create positions and hire personnel	**xxxxx**		
Contract with University of Idaho (UI)	**xxx**		
Train personnel by UI	**xxxxxx**	**xxxx**	**xx**
Procure 1997, 2002, and 2005 images	**xxx**	**xxx**	
Generate CWU maps (UI)		**xxxxxxxxxxx**	**xxxxx**

Publish CWU technical Guides		**xx**	**xxx**
Assess and Evaluate project outcomes	**xx**	**xx**	**xx**
Submit Final report			**x**

Partnerships:

Ron Cacek, General Manager, North Platte Natural Resources District (NRD), Rod L. Horn, General Manager, South Platte NRD, Gary W. Hergert, Professor, UNL Panhandle Research & Extension Center and Rick Allan, Professor, University of Idaho will work cooperatively on this project. The resulting CWU maps, demonstration tools and investigative reports will also be made available to NRCS partners in the two NRDs.

Once funds are secured and approved, the NRD's through UNL will contract with the University of Idaho team for METRIC processing of 1997, 2002 and 2005 LANDSAT images and generation of CWU maps. The University of Idaho and UNL will select and acquire the images from the Center for Earth Resources Observation and Science (EROS), Sioux Falls, South Dakota. The UI team will provide hands-on training to UNL and NRD counterparts on the application of algorithms and calibration techniques.

The UI and UNL teams will utilize the CWU maps to estimate crop coefficients as part of a training exercise for UNL and NRDs. A UNL specialist will assist in converting ET images processed from the satellite images into estimates of differences in actual CWU between water sources and irrigated and rainfed systems and will aggregate total CWU over NRD service areas. The GIS technician will conduct extensive ground truthing to validate the accuracy of the estimates and for classification of crop types to use during sampling of Kc from the CWU maps. UNL will acquire the technical knowledge to process LANDSAT images to create CWU maps. The CWU maps will be used to estimate consumptive water use of agricultural vegetation which can be used to derive water balance maps and reports. (2) The Natural Resources District will use the estimates of CWU, water balances, and specific studies as a basis for developing revised water conservation policies and practices. (3) This dynamic tool will be readily transferable to similar groundwater depleted regions in other parts of Nebraska. This project will provide expertise to NRD's about using the technology to help explain the process of using water balance and crop coefficient information to help manage water resources. The transfer of technology is expected to be cost effective and adopted seamlessly across institutions as "demand" will grow. In the future, the costs of generating CWU maps and for conducting studies will be charged to the NRDs.

Budget:

The major funding source for much of this work is a NRCS Conservation Innovations Grant. These funds will supplement NRD funding to provide their contribution to the larger grant. Funds will be used to hire a GIS technician who will use the SEBAL and METRIC programs to generate the CWU maps. Fringe benefits are calculated at a rate of 28%. The travel

portion of the budget will be used to fund travel for University of Idaho personnel to interact with NRD and UNL personnel.

The equipment portion will provide a computer to run software programs (SEBAL, METRIC, GIS). The supplies portion will primarily be for the purchase of the LANDSAT images from USGS and will include other project specific supplies.

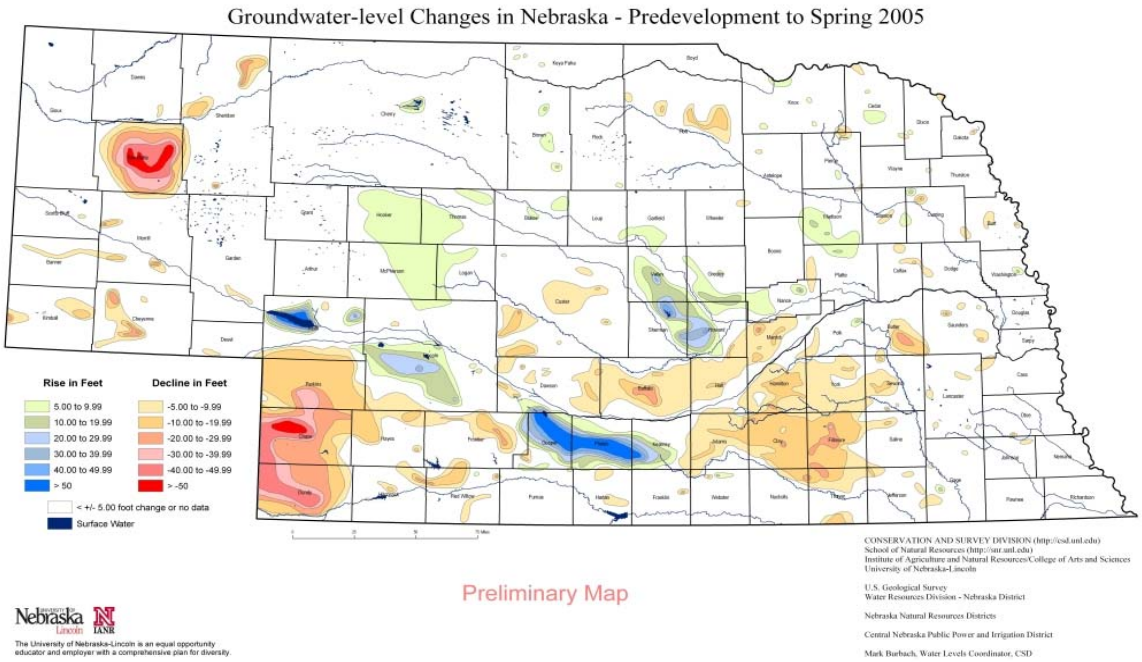


Figure 1

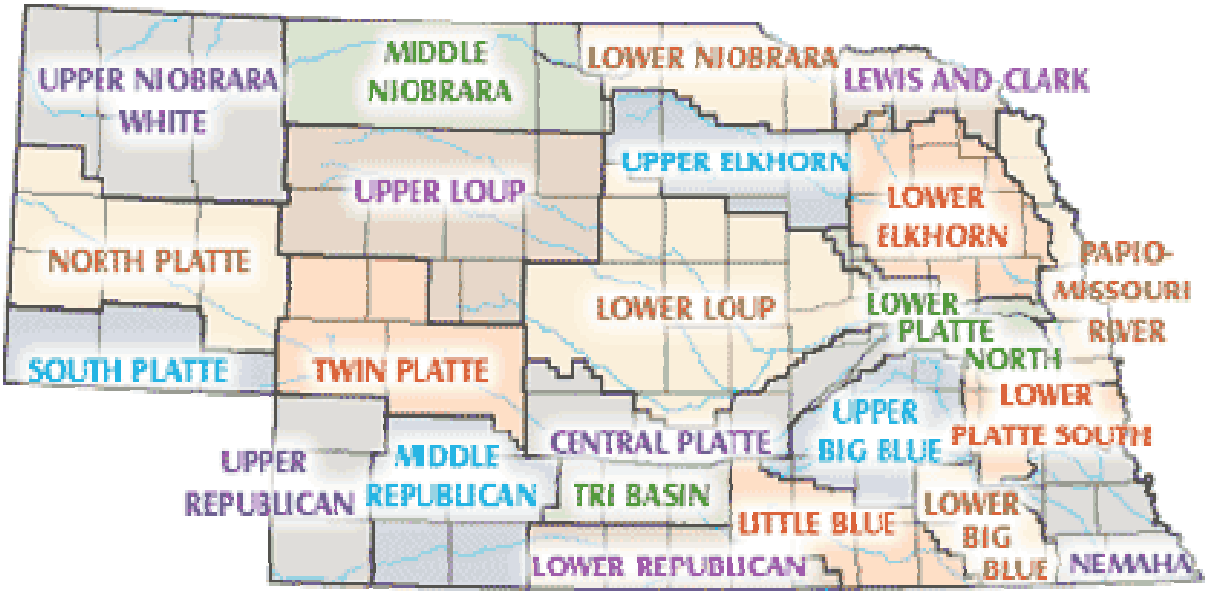
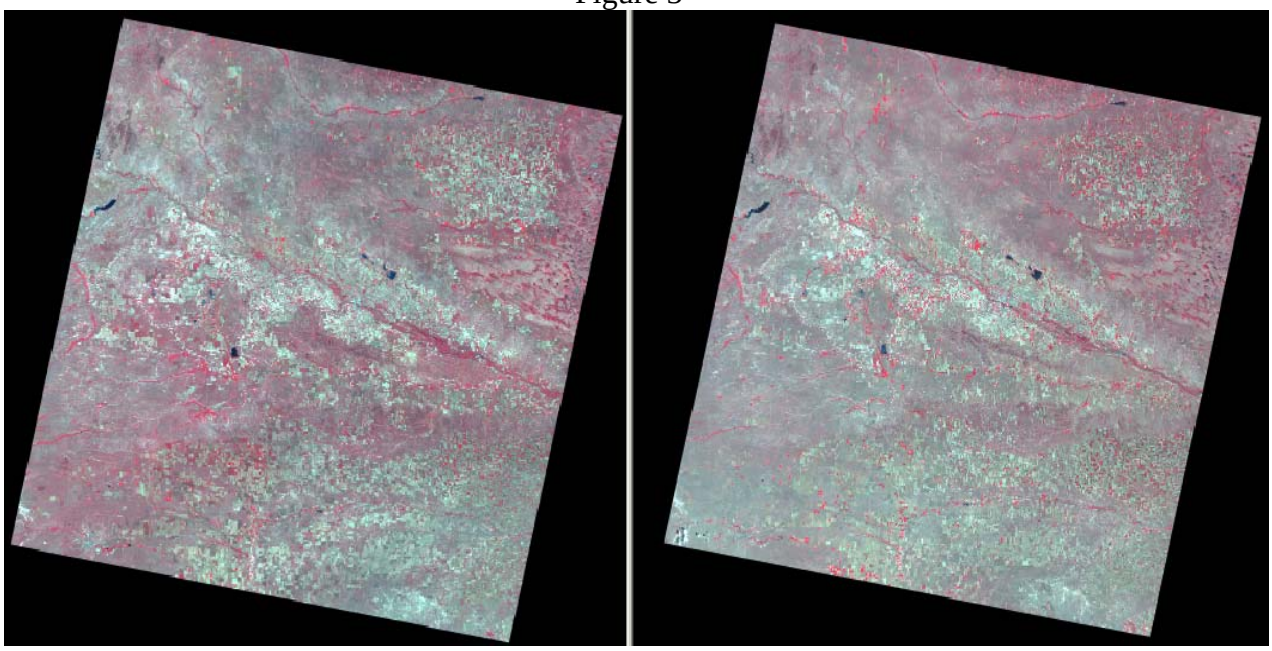


Figure 2

Figure 3



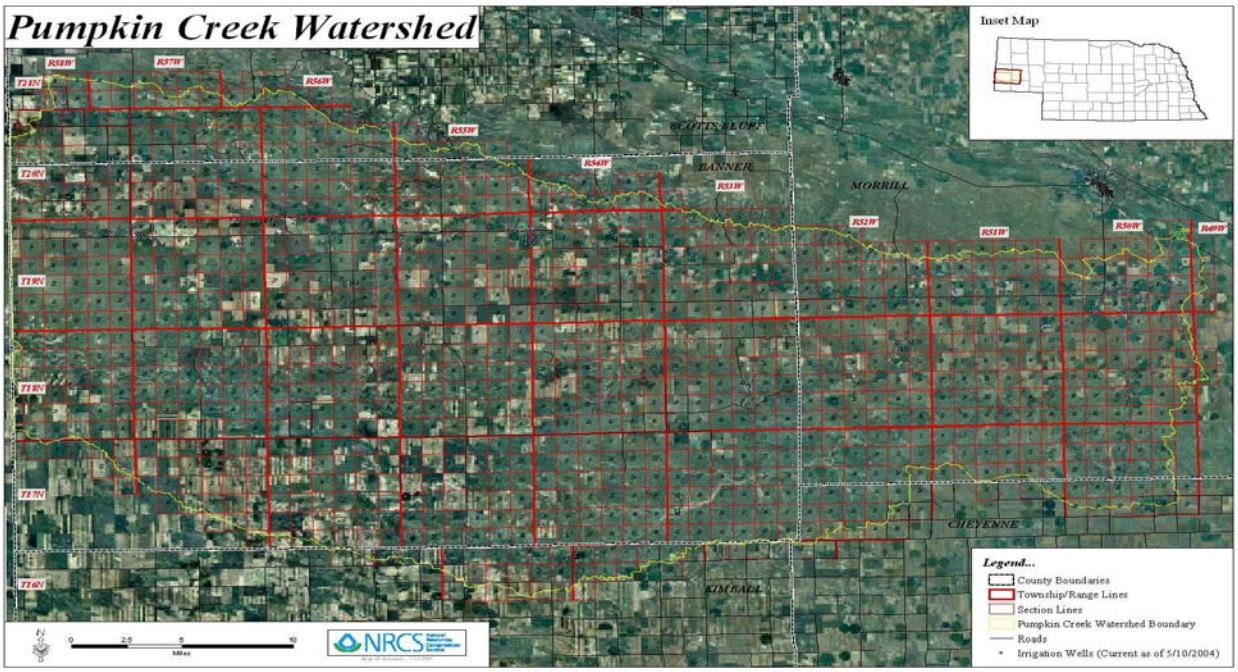

Pumpkin Creek Watershed
Inset Map
R58W
R57W
R56W
R55W
R54W
R53W
R52W
R51W
R50W
R49W
T20N
T19N
T18N
T17N
T16N
SCOTTS BLUFF
BANNER
MORRILL
CHEYENNE
KIMBALL
Legend...
County Boundaries
Township/Range Lines
Section Lines
Pumpkin Creek Watershed Boundary
Roads
Irrigation Wells (Current as of 5/10/2004)
NRCS

Figure 4

Interrelated Water Management Plan Program Funds Application

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APPLICATION BUDGET SUMMARY

SUMMARY for All Years of Project
(If the project is for one year only, use this only page and delete the following budget pages)

Column A	Column B	Column C	Column D	Column E	Column F
Source of Funds ►	**Interrelated Water Plan Program Funds**	**Local Match Funds**			**TOTALS ▼**
Budget Category as it relates to activities described above ▼					
1. Personnel	71,210	49,518			120,728
2. Benefits(28%)	19,939	19,260			39,199
3. Travel	15,000				15,000
4. Operating	5,500				**5,500**
5. LANDSAT images	25,000				25,000
6. Contractual (Univ ID)	110,000				110,000
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
TOTALS ►	246,649	68,778			315,427

Interrelated Water Management Plan Program Funds Application

Deadline for Applications August 28, 2006

BUDGET YEAR: ONE
(This page is used by multi-year grants only. If your project is not a multi-year grant, then ignore or delete this page.)

Column A	Column B	Column C	Column D	Column E	Column F
Source of Funds ▶	**Interrelated Water Plan Program Funds**	**Local Match Funds**			**TOTALS ▼**
Budget Category as it relates to activities described above ▼					
1. Personnel	**71,210**	**16,506**			**39,318**
2. Benefits(28%)	6,388	6,420			**12,808**
3. Travel	6,000				6,000
4. Operating	5,500				5,500
5. Supplies (LANDSAT)	11,000				11,000
6. UI Contractual	40,000				40,000
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
TOTALS ▶	91,700	22,926			114,626

Interrelated Water Management Plan Program Funds Application

Deadline for Applications August 28, 2006

BUDGET YEAR: TWO

(This page is used by multi-year grants only. If your project is not a multi-year grant, then ignore or delete this page.)

Column A	Column B	Column C	Column D	Column E	Column F
Source of Funds ►	**Interrelated Water Plan Program Funds**	**Local Match Funds**			**TOTALS ▼**
Budget Category as it relates to activities described above ▼					
1. Personnel	23,724	16,506			40,230
2. Benefits(28%)	6,643	6,420			13,063
3. Travel	5,000				5,000
4. Operating	0				0
5. Supplies (LANDSAT)	9,000				9,000
6. UI Contractual	40,000				40,000
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
TOTALS ►	84,367	22,926			107,293

Interrelated Water Management Plan Program Funds Application

Deadline for Applications August 28, 2006

BUDGET YEAR: THREE

(This page is used by multi-year grants only. If your project is not a multi-year grant, then ignore or delete this page.)

Column A	Column B	Column C	Column D	Column E	Column F
Source of Funds ►	**Interrelated Water Plan Program Funds**	**Local Match Funds**			**TOTALS ▼**
Budget Category as it relates to activities described above ▼					
1. Personnel	24,673	16,506			41,179
2. Benefits(28%)	6,909	6,420			13,329
3. Travel	4,000				4,000
4. Operating	0				0
5. Supplies (LANDSAT)	5,000				5,000
6. UI Contractual	30,000				30,000
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
TOTALS ►	70,582	22,926			93,508

Interrelated Water Management Plan Program Funds Application

Deadline for Applications August 28, 2006

1. **Have other sources of funding not listed in the Budget Worksheet been approached for project support? If yes, name them and explain the outcome of your request.**

Grant funds (NRCS Conservation Innovation Grant) have been secured by the University of Nebraska with matching funds from the South Platte and North Platte NRDs for the majority of this project. The DNR funds requested will allow the NRDs to add additional resources to enhance the project.

2. **Are all of the matching funds in the Budget Worksheet confirmed? If not, please identify those entities and list the date when confirmation is expected. Explain how you will implement the project if these sources do not confirm participation.**

Both boards of directors (SPNRD & NPNRD) have approved committing these matching funds.

Grant applications and information on grant guidelines and time table can be found on the Department of Natural Resources Web Site: http://www.dnr.ne.gov.

Application Submission:

1. One paper copy of the grant application with the required signatures is to be submitted by **August 28, 2006** to:

   Jeremy Gehle
   Nebraska Department of Natural Resource
   301 Centennial Mall South
   Lincoln, NE 68509-4676

2. One electronic copy is to be emailed by **August 28, 2006** to:

   Jeremy Gehle at: jgehle@dnr.ne.gov